GEOGRAPHIC INFORMATION SYSTEM (GIS) AND SUPPLY CHAIN MANAGEMENT (SCM) - A MANAGER’S PERSPECTIVE

PROF. M.S. SUBHAS¹, VINOD N.SAMBRANI ²

1Faculty, Institute of Management Studies, Kuvempu University, Davangere, Karnataka
2Kousali Institute of Management Studies, Karnataka University, Dharwad, Karnataka

Email: vnsambrani@yahoo.com, vinodsambrani@gmail.com ; drmssubhas@gmail.com

Abstract

A supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. GIS as a tool can be used to map manufacturing, warehouse locations, clients, supplier locations and distribution centers, showing product supply or manufacturing facilities. Geographic Information Systems helps in analyzing and representing the information visually, allowing for greater understanding of the operating environment around the corporate.

GIS can be used to analyze the routes. Route analysis helps us to generate the most efficient route (best route / shortest route) that the vehicle should take between the company and its supply chain link. Alternative routes can also be generated and analyzed. Alternative routes help in rerouting of the supplies in case of problems (either man-made or natural) on one route.

GIS helps in identifying the locations of new depots and warehouses based on the factors like source of incoming materials and the target market to which the stocks will move that is the different links in the supply chain.

Thus when supply chain is integrated with geographic information systems, decisions related to routing, identifying location for warehouses and risk mapping can be done efficiently and presented visually. That is, the visual features can be converted into business variables like cost, gross margin and profit for effective managerial decision making.

There are four major decisions areas in supply chain management viz. 1. Location, 2. Production, 3. Inventory and 4. Transportation (Logistics). In this paper the focus is on the transportation decision of the supply chain management when integrated with GIS.

Keywords: Supply Chain Management, Geographic Information Systems, Routing, Location, Alternate Routes, Risk Mapping.

¹ Professor, Kousali Institute of Management Studies, Karnataka University, Dharwad. Email: drmssubhas@gmail.com

² Faculty, Inst.of Management Studies, Kuvempu University, P.G.Centre, Shivagangotri, Davangere. Email: vnsambrani@yahoo.com
Introduction:

Supply Chain Management (SCM) is the process of planning and management of materials, information and financial flow in a network consisting of manufacturers, distributors, vendors and customers with the objective of reducing operating costs and improving customer service\(^1\).

The advent of Global markets has brought a great change in the way of doing business: From manufacturer’s point of view, manufacturers are concentrating on their core competencies and outsourcing components and services from third parties. Secondly from consumer’s point of view, better products are available at lower prices. This means companies large and small need to streamline their supply chain (SC) to gain competitive advantage. The focus is shifting from the performance of single firm to competitive advantage of the entire supply chain.

Logistics strategies, in particular transportation decisions, can be considered as key factors to increase supply chain effectiveness. Transportation services play an important role in seamless supply chain operations, moving in-bound materials from supply sites to manufacturing facilities, repositioning inventory among different plants and distribution centres and delivering finished products to customers.

Organizations are spending on software and new technologies for seamless integration of the supply chain, to increase overall supply chain profitability. Companies are turning to Geographic Information Systems (GIS) as a key component in their supply chain software. Mapping software provides an easy way for users to visualize data. "It gets the point across a little easier than raw data"\(^2\)

There are four major decision areas in supply chain management viz, 1. Location, 2. Production, 3. Inventory and 4. Transportation\(^3\). In this paper the focus is on the transportation (Logistics) decision of the supply chain management, in specific the routing decision. Which route to take is a very crucial managerial decision because routing decision leads to further decisions regarding the logistic expenses, travel time, travel distance? A Spatial Decision Support System.
(SDSS) is developed for route analysis and route generation (Best route and alternatives to the best route). The spatial component of the DSS helps managers make better business decisions.

AN OVERVIEW OF GIS

GIS is considered a path-breaking technology for managing natural resources and town planning in developing countries. There are different definitions for GIS, each developed from a different perspective. Some focus on the map connection, some stress the database and others emphasis applications such as decision support systems. An analysis of the acronym explains everything:

A GIS is a computer system for managing spatial data,
The word geographic implies that location of the data items are known in terms of geographic coordinates (Latitude and Longitude). The word information implies that the data in a GIS are organized to yield useful knowledge, often as coloured maps and images, but also as statistical graphics, tables and various onscreen responses to interactive queries. The word system implies that a GIS is made up from several interrelated and linked components with different functions. Thus GIS has functional capabilities for data capture, input, manipulation, transformation, visualization, combination, query, analysis, modeling and output.

The capabilities of the GIS system are expected to bring transformations in a business organization, ranging from the way routing decisions are planned to the decisions related to opening of new facilities. The three different views in GIS enable its use for different purposes:

1. The Database View (Non Spatial Information), also known as the geo database, describes the world in geographic terms. It includes data related to terrain, describes a location in terms of longitude and latitude, includes information like place name, address and cartographic information.

2. The Map View (Spatial Information), also known as the geo visualization view, includes interactive maps, 3D scenes, summary charts and tables, time-based views, and schematic views of network relationships.

3. The Model View, also known as the geo processing view, includes the geographic data set and operators (called tools) on this data set. These operators are used on the geographic data set (including satellite imagery, information on road, soil etc) to arrive at a new data set of one’s interest.

These three different views and the ability of GIS to keep spatial and non-spatial data in different layers enables users to process data according to any combination of layers. This facilitates various spatial operations like overlay, union, intersection and clipping of maps with corresponding operations performed on the linked database.

Associating data with features lets users organize data based on the geographic location of each record in the data. This geographic organization, presented as a map, reveals spatial relationships and influences that cannot be identified in traditional tabular views of data.
Geographically organizing data allows the utilization of new data that may not have anything in common with existing data other than location, thus churning out new data sets. This information can be used to arrive at a decision. In this way, GIS acts as a decision making tool.

GIS AS SPATIAL DECISION SUPPORT SYSTEM

For GIS’s to support decision making they must be viewed as spatial decision support systems (SDSS). These can be defined as “Interactive computer based systems that help decision makers to utilize data and models in the solution of unstructured problems”.

The four key modules of an DSS are:

1. The Decision Model
2. The Interface
3. Analysis Module
4. Database Management System.

In a SDSS, the modules will be specifically designed to handle spatially referenced data. The DBMS will integrate locational, topological and thematic data types to support cartographic (Map) display, spatial query and analytical modeling as a variety of spatial scales for a large number of variables. The analysis module will have a spatial analysis structure which provides user with flexible and comprehensive spatial analysis and modeling capabilities. The model building module will support the construction and display of a range of spatial choice models. The user interface must display a wide range of data types including graphical data and must be relatively sophisticated in order to disseminate relatively complex datasets in an amenable form. A GIS then has all of the features of a DSS and the ability to accommodate spatially referenced data, thus can be used as a generator of SDSS.

INFORMATION TECHNOLOGY AND SUPPLY CHAIN MANAGEMENT

Information technology (IT) includes a set of powerful tools that can lead to the failure or success of a supply chain process. Technologies like internet, intranet, extranets and groupwares facilitate the sharing of information using (distributed) common databases. These allow sharing the information not just within the functional divisions of an enterprise but upstream and downstream of the supply chain.

Electronic Data Interchange (EDI), one of the earliest uses of information technology for SCM is used to place orders, inventory database can be shared between the manufacturer and the supplies for efficient implementation of JIT inventory; for vendor managed inventory (VMI) this sharing is a must. Internet and EDI can be used by the customer to monitor the status of the order placed, request changes in the order and vice-versa, they may be used to inform the customers about the status of their order, besides being used for billing etc.
Other supply chain management tools like supply chain configuration tools (for strategic decision making by determining the number, capacity requirements besides location of facilities etc.); demand planning tools to assist management in understanding the key drivers of demand using sophisticated analytical tools and with provision for interfacing with external data. Supply planning tools to assist management with decisions such as which products to make, how to make them, what order to make them in and where to source materials from? All these tools are helpful in managerial decision making².

A look at these tools and their solutions suggest that, all the variables for these tools are from within the organization, with little effort the variables can be controlled for efficiency.

Transportation (logistics) on the other hand is an external variable and needs to be controlled. Transportation and distribution planning and management tools assist in the planning of how much to move- which item(s) - where? It helps in load creation and sequencing, vehicle-scheduling, routing decisions. Other information technologies used for managing transportation are bar coding, the most commonly used automatic identification technology, imaging, RF technology for real time inventory control and data tracking, expert systems and lastly ERP solutions, which provide the transactional data handling support. More and more DSS developers are providing interfacing/integration capabilities with ERP software for advanced tools of decision making support. Today the focus is shifting form DSS to SDSS, this is where GIS plays a important role.

GIS AND SUPPLY CHAIN MANAGEMENT

Geographical Information Systems (GIS) offer a valuable supply chain risk management tool. GIS analysis provides the opportunity to represent this information visually. GIS analysis allows the decision maker to visualize a complete company profile to include manufacturer, office and warehouse locations, and employee, client, customers, distributor and supplier locations. Relationships can be drawn between these locations, allowing for the company’s supply chain to be identified and monitored.

Various types of risks—either man-made or natural threats can be mapped, layered and presented. Historical risk trends such as earthquake, floods, strikes etc. can be over layered against the network to additionally determine an operating risk environment⁹.

GIS helps businesses to answer supply chain management questions like

1. What is my drive time from the central facility?
2. How long will it take to reach delivery locations?
3. Which customer should be in separate service areas?
4. How can I track goods through my supply chain?

Further GIS helps businesses answer transportation questions like

1. What is the best route for the delivery trucks?
2. What are the alternative routes in case of problems on one route¹⁰.
Route analysis is the operation which aims at minimizing the cost of travel involved in transporting goods from one location to another whether in terms of trips required or time or distance or a combination of these.

Presenting supply chain performance data in the form of a spreadsheet neglects the real world influence of geography on transportation. For example one retailer knew the nodes of the supply chain well, but when the routes between the manufacturer and distribution warehouse were actually mapped, it was found that every shipment ended up crossing the same bridge. The entire company’s operations would be negatively impacted if this particular bridge was closed. Thus when supply chain performances are mapped, problems are immediately visible and alternatives, such as rerouting to another route or form another facility are much easier to explore. Proper routing can help the organizations achieve their competitive priority and increase the overall supply chain profitability. GIS images are not just pictures on the map for a manager, they are spatial variables. Integration of the spatial data along with the attribute data helps manager do “what-if analysis” and actually see the implication / impact of the result on the operating area. Thus GIS tool needs to be customized to suit manager’s requirements and help him answer the above questions for operating efficiency. A SDSS for route analysis and route generation is developed using Visual Basic as the front-end tool (User Interface) and ArcView 3.2 as the back-end tool. The sample area considered for the study is Dharwad district of Karnataka State.

STUDY AREA

The SDSS is developed using the digitized road and settlements map of Dharwad district of Karnataka State. The routes are generated between Hubli and Kalaghatgi talukas of Dharwd district.
SYSTEM DEVELOPMENT
The SDSS is developed using Visual Basic 6 as the front end tool. All the spatial and attribute data is stored in Arc View 3.2, which acts as the back-end tool. Shortest path and Alternate path module has been developed by modifying the routing algorithm developed by Dijkstra\(^*\). The alternate paths to the best path is generated by discouraging re-use of most street segments used by the best distance route and all previously generated alternate routes. The method for discouraging re-use is to artificially inflate the costs (distance) associated with using those previously-used street segments.\(^*\)

SPATIAL DECISION SUPPORT SYSTEM FRAMEWORK

- GIS Spatial Data
- Attribute Database
- User Interface
  - (Visual Basic 6.0)
  - User selects origin and destination

1. Shortest Path Module
2. Alternative paths to the best Path Module
3. District Maps
4. Road Maps
  a. National Highway
  b. Major District Roads
5. Settlements Maps
6. Map Display
  1. Shortest Path
  2. Alternate paths to the best path

Figure 1.1: SDSS Model for Route Generation

SDSS APPLICATION WITH SAMPLE OUTPUT

* Dijkstra's algorithm is of use when working with directional graphs. It constructs the shortest path between a starting-node and a goal-node. It is assumed that every link between two nodes has a certain cost or distance, and this algorithm finds the path between the two given nodes with the lowest cost or distance

**Figure 1.2:** Route Generation between Hubli and Kalaghatgi.

**Figure 1.3:** Travel time Calculation
CONCLUSION

GIS analysis is more than the use of mapping software or the ability to plot points on a map. It is the ability to draw relationships spatially and to identify value in each relationship. The graphing and network display capabilities of GIS are well suited to supply chain management. Manufacturing and distribution facilities can be represented on a map. The system developed allows the decision maker to have prior information about the road network, the shortest path and the alternative paths between manufacturing and distribution facilities. This information can be used to make routing analysis and help organizations achieve their competitive priority and increase the overall supply chain profitability. Based on the average travel speed the travel time can also be calculated. Travel speed acts as a proxy to traffic data.

GIS provides a uniform environment to integrate the data for numerous transportation purposes. Once spatially referenced, the data can be used in many other applications, thus adding value to the data and value to the planning process. Attribute data like source of incoming materials and the target market to which the stocks will move can be integrated into the SDSS that is developed. This SDSS can now be used in identifying the locations of new depots and warehouses. Thus by integrating new data into the base SDSS one can develop new applications. Though the application might look simple, it has great potential for profitability because managers can visually see the route, its terrain, alternative routes on his computer. This information can be converted in business variables like cost, gross margins and profits for making effective business decisions regarding routing.
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